Laser Diagnostics of Dispersive Systems with Supercritical Component

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Abstract—Proposed a novel approach to diagnostics of nanostructured multiphase systems with supercritical components with the use of statistical and correlation analysis of speckle-modulated laser light.

Keywords—light scattering; speckle intensity fluctuation

We consider a novel approach to diagnostics of nanostructured multiphase systems with supercritical components with the use of statistical and correlation analysis of speckle-modulated laser light, which is multiply scattered by a probed system in the course of slow controllable variations of its thermodynamic parameters (the temperature and the density of supercritical component). The examined systems were the polymer and composite porous layers saturated by a supercritical fluid (carbon dioxide). The parameters of examined system such as the transfer rate of supercritical component in a host porous medium, the time of system relaxation after jump-like change of the density of supercritical component, and the current value of density can be obtained on the base of analysis of statistical characteristics of forward scattered laser light (the intensity of coherent component, the scintillation index, the correlation time of intensity fluctuations, etc.). The obtained experimental data are interpreted with the use of phenomenological model of coherent light transfer in a multiple scattering two-component random medium with the continuously varying refractive index of one component.

Figure 1 displays behavior of the normalized power of speckle intensity fluctuations in the course of viscoelastic relaxation of the porous matrix after jump-like changes in the thermodynamic parameters of the system. Normalized power of the speckle intensity fluctuations is calculated by the following formula:

\[
\Sigma(t) = \Sigma(n \cdot \Delta t) = \frac{1}{M} \sum_{m=1}^{M} \left( \frac{1}{L} \sum_{k=1}^{L} \frac{\sum_{n=1}^{N} \left( f_{m}^{n+k} \right)^{2}}{\sum_{n=1}^{N} \left( \tilde{f}_{m}^{n} \right)^{2}} \right)
\]

where \( f_{m}^{n+k} \) is the fluctuating component of the m-th pixel brightness.

Thus ascertained that: the movement of fluid in the porous matrix during the transition from one equilibrium thermodynamic system state to another is controlled by not only its filtering process, depending on the fluid density distribution in the matrix, its viscosity and permeability of the matrix, but also viscoelastic relaxation process matrix; experiments with porous polymer layers found that the relaxation time of the system is much higher than the hydrodynamic relaxation time of the fluid density in the matrix.

Fig. 1. Normalized power of speckle intensity fluctuations (sample: teflon layer (thickness 100 microns)), 1 – \( T=298.16 \) K, 2 – \( T=300.66 \) K, 3 – \( T=303.66 \) K. The dash line corresponds to 1/e level.